

Neutron star mass and radius measurements from atmospheric model fits to X-ray burst cooling tail spectra

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Abstract

© ESO, 2017. Observations of thermonuclear X-ray bursts from accreting neutron stars (NSs) in low-mass X-ray binary systems can be used to constrain NS masses and radii. Most previous work of this type has set these constraints using Planck function fits as a proxy: The models and the data are both fit with diluted blackbody functions to yield normalizations and temperatures that are then compared with each other. For the first time, we here fit atmosphere models of X-ray bursting NSs directly to the observed spectra. We present a hierarchical Bayesian fitting framework that uses current X-ray bursting NS atmosphere models with realistic opacities and relativistic exact Compton scattering kernels as a model for the surface emission. We test our approach against synthetic data and find that for data that are well described by our model, we can obtain robust radius, mass, distance, and composition measurements. We then apply our technique to Rossi X-ray Timing Explorer observations of five hard-state X-ray bursts from 4U 1702-429. Our joint fit to all five bursts shows that the theoretical atmosphere models describe the data well, but there are still some unmodeled features in the spectrum corresponding to a relative error of 1-5% of the energy flux. After marginalizing over this intrinsic scatter, we find that at 68% credibility, the circumferential radius of the NS in 4U 1702-429 is $R = 12.4 \pm 0.4$ km, the gravitational mass is $M = 1.9 \pm 0.3 M_{\odot}$, the distance is $5.1 < D / \text{kpc} < 6.2$, and the hydrogen mass fraction is $X < 0.09$.

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Keywords

Dense matter, Stars: neutron, X-rays: Binaries, X-rays: Bursts

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